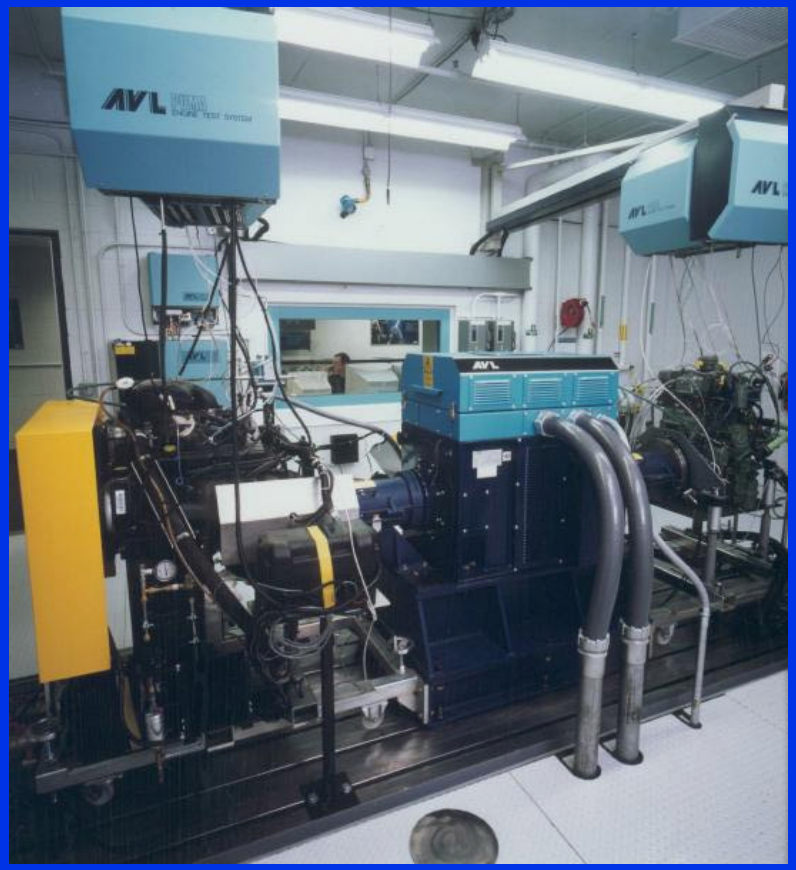
Emissions Technologies for Off-Highway Compression Ignition Engines.

Peter Church

February 3, 2000

AVL Powertrain Engineering

Who is AVL ?



Largest Independent Powertrain Consulting Company

2400 employees worldwide

Privately owned

Total revenues more than $300m

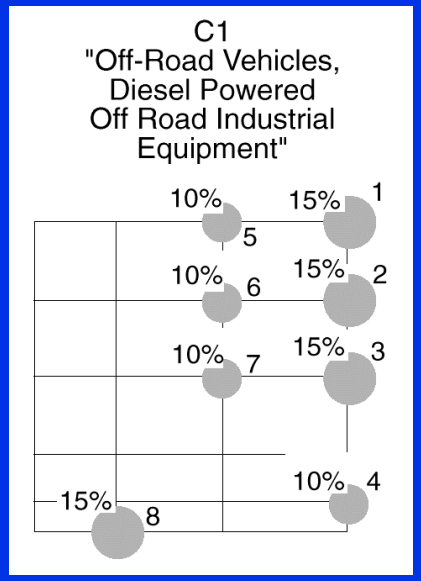
Based in Graz, Austria

US facility in Plymouth, MI

Business areas:

- **Development of powertrain systems**
- **Instrumentation and test systems**

US EPA Non-Road Diesel Emission Limits 75 - 450 kw



Test cycle and particulate limit to be reviewed by the EPA in 2001

NMHC+NOx /PM [g/kW-h]

ISO 8178 C1 Test Cycle

	Tier 1	Tier 2	Tier 3
75<kW<130	(NOx) 9.2/--	6.6/0.3	
130<kW<225	(NOx) 9.2/0.54	6.6/0.2	4.0/*0.2*
225<kW<450	(NOx) 9.2/0.54	6.4/0.2	4.0/*0.2*

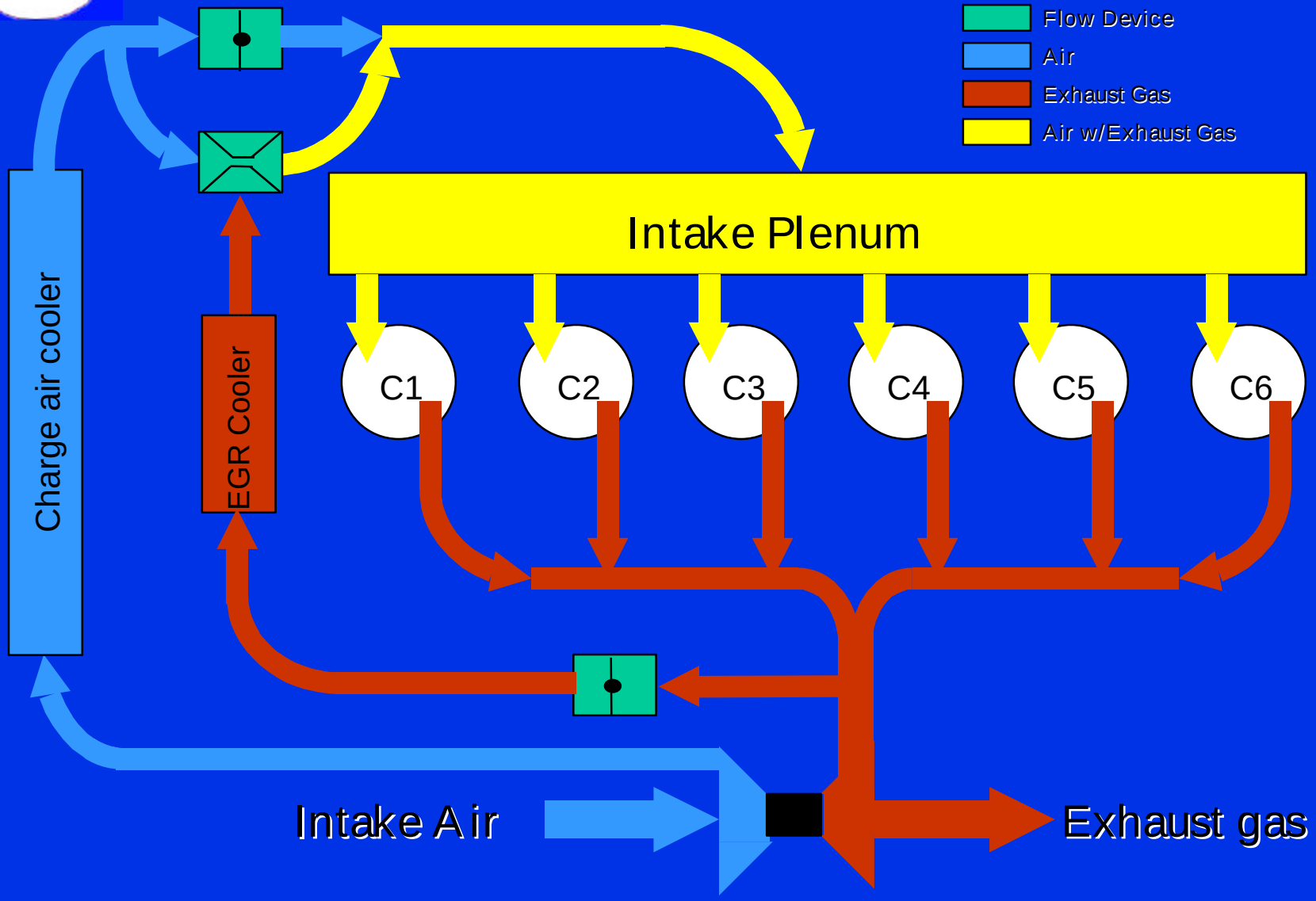
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

Technical Options For Tier 3

AVL considers the following technologies to be feasible options for Tier 3 non-road emissions control:

- Cooled Exhaust Gas Recirculation
- Advanced fuel system technology
- Improved diesel fuel
- Exhaust aftertreatment

COOLED EGR - BYPASS FLOW VENTURI CONCEPT



Bypass Flow Venturi Concept:

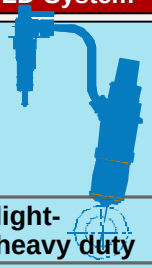
Characteristics:

- Venturi used to aid flow of exhaust gas to the intake manifold
- EGR rates of 6-8%at intermediate speed
- Moderate EGR rates at rated speed
- Moderate to high heat rejection rate

Applications:

- Applications requiring good fuel economy
- Engines with little or no injection rate control or aftertreatment

ADVANCED FUEL SYSTEMS - CAM DRIVEN TYPES

	Pump-Line-Nozzle Injection Systems			Unit Injector Systems
	Sleeve Timing In-Line Inj. Pump	High Pressure Rotary Pump	Unit Pump PLD-System	
				
Applicable Engine Class	medium-heavy duty	light-medium duty	light-heavy duty	light-heavy duty
Current Maximum Injection Pressure (bar)	1450	1400	1800	2200
Potential Maximum Injection Pressure (bar)	1600	1500	2200	2500
Natural Pressure Characteristic				
Injection Rate Shaping Mech.:	TSI, RSN Pre Inj. Helix (Pilot)	TSI, RSN	TSI, RSN	TSI, SID, RSN
Injection Rate Shaping Electron.:	-	-	Pilot	Pilot
Development and Application Activity	medium	high	high	medium (EU) high (USA)

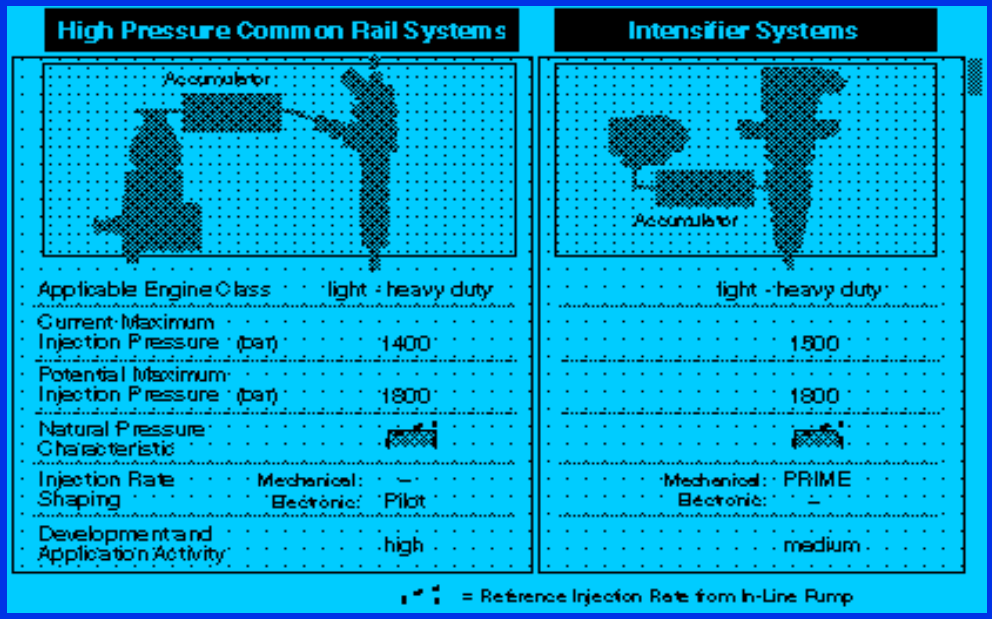
 = Reference Injection Rate from In-Line Pump

61033

Unit pump and Unit injector systems are the preferred cam driven types:

- **Higher maximum injection pressure and favorable pressure characteristics**
- **Capable of pilot injection and “boot” injection**

ADVANCED FUEL SYSTEMS - COMMON RAIL TYPES



Both systems will have similar capabilities:

•Hydraulic intensifier system may prove advantageous if hydraulic power from the pump can be used with other vehicle systems. New digital valve types can provide pilot injection.

•High pressure common rail system could share high volume with passenger car types, reducing cost

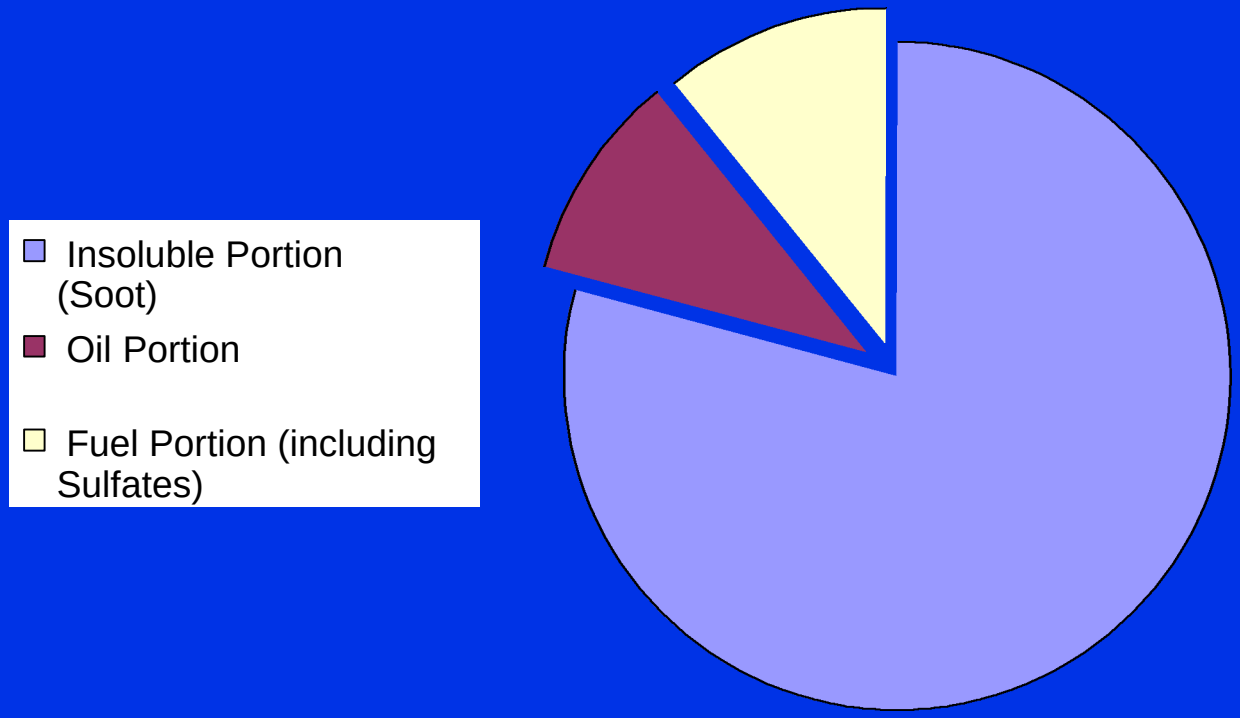
ADVANCED FUEL SYSTEMS - ELECTRONIC CONTROL

Electronic control provides many advantages at Tier 3 emissions levels:

- **Reduced soot in oil for engines**
- **Improved cold starting**
- **Rating flexibility**
- **Reduced combustion noise**

Particulate reduction:

- Reduced sulfur content provides a direct reduction in particulates due to reduced sulfates in the particulate matter



For off-highway diesel engines, fuel sulfur level will be critical if aftertreatment is employed:

Particulate reduction:

- **CRT (Continuously regenerating trap) - Requires fuel Sulfur levels below 50 ppm**
- **Oxidation catalyst - Requires fuel Sulfur levels below 500 ppm**

NOx Reduction:

- **De-NOx catalysts using diesel fuel post-injection require fuel Sulfur levels below 10 ppm**

FUEL ADDITIVE SUPPORTED REGENERATION

- SCR (Selective Catalytic Reduction) - Requires a separate onboard supply of reducing agent.
- OBD is required to indicate lack of additive and to control trap loading.
- Low Sulfur fuel is not required with SCR

TIER 3 - DURABILITY CONSIDERATIONS

Durability connects emissions reductions that are possible to emissions reductions that are practical. The main durability issues for Tier 3 are:

- **EGR control component durability**
- **Turbocharger durability**
- **Soot loading in the lube oil**
- **Aftertreatment device durability**